Understand Advanced Java Completable Future Features: Implementing FuturesCollector

Douglas C. Schmidt
d.schmidt@vanderbilt.edu
www.dre.vanderbilt.edu/~schmidt

Professor of Computer Science
Institute for Software Integrated Systems
Vanderbilt University
Nashville, Tennessee, USA
Learning Objectives in this Part of the Lesson

- Understand advanced features of completable futures, e.g.
  - Factory methods initiate async computations
  - Completion stage methods chain together actions to perform async result processing & composition
- Arbitrary-arity methods that process futures in bulk
  - Wrap the allOf() method to work with the Java streams framework

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/CompletableFuture.html
Implementing the FuturesCollector Class
Implementing the FuturesCollector Class

- FuturesCollector returns a completable future to a stream of big fractions that are being reduced and multiplied asynchronously

```java
static void testFractionMultiplications1() {
    ...
    Stream.generate(() -> makeBigFraction(new Random(), false))
        .limit(sMAX_FRACTIONS)
        .map(reduceAndMultiplyFractions)
        .collect(FuturesCollector.toFuture())
        .thenAccept(this::sortAndPrintList);
}
```

*collect() converts a stream of completable futures into a single completable future*

See [github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex8](http://github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex8)
Implementing the FuturesCollector Class

- FuturesCollector wraps allOf() to work with the Java streams framework

```java
<<Java Interface>>

Collector<T,A,R>

- supplier(Supplier<A>
- accumulator(BiConsumer<A,T>)
- combiner(BinaryOperator<A>)
- finisher(Function<A,R>)
- characteristics(Set<Characteristics>)

<<Java Class>>

FuturesCollector<T>

- FuturesCollector()
- supplier(Supplier<List<CompletableFuture<T>>>)
- accumulator(BiConsumer<List<CompletableFuture<T>>,CompletableFuture<T>>)
- combiner(BinaryOperator<List<CompletableFuture<T>>,CompletableFuture<T>>)
- finisher(Function<List<CompletableFuture<T>>,CompletableFuture<List<T>>>)
- characteristics(Set)
- toFuture(CompletableFuture<T>,?,CompletableFuture<List<T>>>

See Java8/ex8/utils/FuturesCollector.java
Implementing the FuturesCollector Class

- FuturesCollector wraps `allOf()` to work with the Java streams framework.
- Converts a *stream* of completable futures into a *single* completable future that’s triggered when *all* futures in the stream complete.
Implementing the FuturesCollector Class

- FuturesCollector wraps allOf() to work with the Java streams framework
- Converts a stream of completable futures into a single completable future that’s triggered when all futures in the stream complete
- Implements the Collector interface

See [docs.oracle.com/javase/8/docs/api/java/util/stream/Collector.html](docs.oracle.com/javase/8/docs/api/java/util/stream/Collector.html)
### Implementing the FuturesCollector Class

- FuturesCollector wraps `allOf()` to work with the Java streams framework
  - Converts a *stream* of completable futures into a *single* completable future that’s triggered when *all* futures in the stream complete
- Implements the Collector interface

#### Java Interface

```java
public interface Collector<T,A,R> {
    A supplier();
    BiConsumer<A,T> accumulator();
    BinaryOperator<A> combiner();
    Function<List<T>,R> finisher();
    Set<Characteristics> characteristics();
}
```

#### Java Class

```java
public class FuturesCollector<T> {
    FuturesCollector()
    Supplier<List<CompletableFuture<T>>> supplier();
    BiConsumer<List<CompletableFuture<T>>, CompletableFuture<T>> accumulator();
    BinaryOperator<CompletableFuture<T>> combiner();
    Function<List<CompletableFuture<T>>, CompletableFuture<T>> finisher();
    Set CHARACTERISTICS
    Collector<CompletableFuture<T>, ?, CompletableFuture<T>> toFuture();
}
```

A collector accumulates input stream elements into a mutable result container
Implementing the FuturesCollector Class

- FuturesCollector wraps allOf() to work with the Java streams framework

```java
<<Java Interface>>
Collector<T,A,R>

- supplier(): Supplier<A>
- accumulator(): BiConsumer<A,T>
- combiner(): BinaryOperator<A>
- finisher(): Function<A,R>
- characteristics(): Set<Characteristics>
```

```java
<<Java Class>>
FuturesCollector<T>

- FuturesCollector()
- supplier(): Supplier<List<CompletableFuture<T>>>
- accumulator(): BiConsumer<List<CompletableFuture<T>>,CompletableFuture<T>>
- combiner(): BinaryOperator<List<CompletableFuture<T>>>
- finisher(): Function<List<CompletableFuture<T>>,CompletableFuture<List<T>>>
- characteristics(): Set
- toFuture(): Collector<CompletableFuture<T>,?,CompletableFuture<List<T>>>
```

FuturesCollector provides a powerful wrapper for some complex code!!!
Implementing the FuturesCollector Class

• FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> implements Collector<CompletableFuture<T>, List<CompletableFuture<T>>, CompletableFuture<List<T>>> {
    ...
```

Implements a custom collector

See docs.oracle.com/javase/8/docs/api/java/util/stream/Collector.html
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
class FuturesCollector<T> implements Collector<CompletableFuture<T>,
List<CompletableFuture<T>>,
CompletableFuture<List<T>>> {
...
```

*The type of input elements in the stream*
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T>
    implements Collector<CompletableFuture<T>,
                       List<CompletableFuture<T>>,
                       CompletableFuture<List<T>>> {
...
```

*The mutable result container type*
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
class FuturesCollector<T> implements Collector<CompletableFuture<T>,
    List<CompletableFuture<T>>,
    CompletableFuture<List<T>>> {

    ...
```

The result type of final output of the collector
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> implements Collector<CompletableFuture<T>,
    List<CompletableFuture<T>>,
    CompletableFuture<List<T>>> {
    public Supplier<List<CompletableFuture<T>>> supplier() {
        return ArrayList::new;
    }

    public BiConsumer<List<CompletableFuture<T>>,
        CompletableFuture<T>> accumulator() {
        return List::add;
    }

    ...
}
```

This factory method returns a supplier used by the Java streams collector framework to create a new mutable array list container
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T>
    implements Collector<CompletableFuture<T>,
                        List<CompletableFuture<T>>,
                        CompletableFuture<List<T>>> {
    public Supplier<List<CompletableFuture<T>>> supplier() {
        return ArrayList::new;
    }

    public BiConsumer<List<CompletableFuture<T>>,
                      CompletableFuture<T>> accumulator() {
        return List::add;
    }

    ...
}
```

This mutable result container stores a list of completable futures of type T
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T>
    implements Collector<CompletableFuture<T>,
                              List<CompletableFuture<T>>,
                              CompletableFuture<List<T>>> {
    public Supplier<List<CompletableFuture<T>>> supplier() {
        return ArrayList::new;
    }

    public BiConsumer<List<CompletableFuture<T>>,
                       CompletableFuture<T>> accumulator()
    { return List::add; } 
    ...
}
```

This factory method returns a bi-consumer used by the Java streams collector framework to add a new completable future into the mutable array list container.

This method is only ever called in a single thread (so no locks are needed).
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> {
    ...
    public BinaryOperator<List<CompletableFuture<T>>> combiner() {
        return (List<CompletableFuture<T>> one, List<CompletableFuture<T>> another) -> {
            one.addAll(another);
            return one;
        };
    }
    ...
}
```

This factory method returns a binary operator that merges two partial array list results into a single array list (only relevant for parallel streams)

This method is only ever called in a single thread (so no locks are needed)
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> {
...

    public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
        return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0])).thenApply(v -> futures.stream().map(CompletableFuture::join).collect(toList()));
    }
...
```

This factory method returns a function used by the Java streams collector framework to transform the array list mutable result container to the completable future result type.
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> {
    ...
    public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
        return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0])).
            thenApply(v -> futures.stream().map(CompletableFuture::join).collect(toList()));
    }
    ...
}
```

Reference to the mutable result container, which is an ArrayList.
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface
  
  ```java
  public class FuturesCollector<T> {
      ...
      public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
          return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0])).
          .thenApply(v -> futures.stream()
                  .map(CompletableFuture::join)
                  .collect(toList()));
      }
      ...
  }
  ```

  Convert the list of futures to an array of futures & pass to allOf() to obtain a future that will complete when all futures complete.
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> {
    ...
    public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
        return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0]))
            .thenApply(v -> futures.stream()
                .map(CompletableFuture::join)
                .collect(toList()));
    }
    ...
}
```

*FuturesCollector* implements all methods in the Collector interface. When all futures have completed, get a single future to a list of joined elements of type T.
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
class FuturesCollector<T> {
    ...
    public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
        return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0])).thenApply(v -> futures.stream().map(CompletableFuture::join).collect(toList()));
    }
    ...
}
```

Convert the array list of futures into a stream of futures
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
class FuturesCollector<T> {
    ...

    public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
        return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0])).
            thenApply(v -> futures.stream().map(CompletableFuture::join).collect(toList()));
    }
    ...
}
```

*This call to join() will never block!*
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
class FuturesCollector<T> {
    public Function<List<CompletableFuture<T>>, CompletableFuture<List<T>>> finisher() {
        return futures -> CompletableFuture.allOf(futures.toArray(new CompletableFuture[0])).thenApply(v -> futures.stream().map(CompletableFuture::join).collect(toList()));
    }
}
```

Return a future to a list of elements of T
Implementing the FuturesCollector Class

- FuturesCollector is used to return a completable future to a list of big fractions that are being reduced & multiplied asynchronously.

```java
static void testFractionMultiplications1() {
    ...
    Stream.generate(() -> makeBigFraction(new Random(), false))
        .limit(sMAX_FRACTIONS)
        .map(reduceAndMultiplyFraction)
        .collect(FuturesCollector.toFuture())
        .thenAccept(this::sortAndPrintList);
}
```

*thenAccept() is called only after the future returned from collect() completes.*

See lesson on “Advanced Java Completable Future Features: Applying Completion Stage Methods”
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> {
    ...
    public Set characteristics() {
        return Collections.singleton(Characteristics.UNORDERED);
    }
}
```

```
public static <T> Collector<CompletableFuture<T>, ?, CompletableFuture<List<T>>>
    toFuture() {
        return new FuturesCollector<>();
    }
}
```

FuturesCollector is thus a *non-concurrent* collector
Implementing the FuturesCollector Class

- FuturesCollector implements all methods in the Collector interface

```java
public class FuturesCollector<T> {
    ...
    public Set characteristics() {
        return Collections.singleton(Characteristics.UNORDERED);
    }
}
```

This static factory method creates a new FuturesCollector

```java
public static <T> Collector<CompletableFuture<T>, ?, CompletableFuture<List<T>>> toFuture() {
    return new FuturesCollector<>();
}
```
End of Understand Advanced Java Completable Future Features: Implementing FuturesCollector